A METHOD TO ASSESS LOG VALUE LOSS CAUSED BY CROSS-CUTTING PRACTICE ON THE SKIDSITE

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ABSTRACT

A program called AVIS, Assessment of Value by Individual Stems, has been developed to enable the comparison of what the skidworkers are able to achieve in crosscutting the stems and the optimal conversion for these stems. This program uses the same optimal crosscutting algorithm as the planning system MARVL.

To develop a field measurement procedure and to test the method, a full-scale trial was undertaken in Kinleith Forest.

A value loss of 26% from sub-optimal crosscutting was shown by AVIS with the particular mix of log types and values used in this trial. This was reduced to 11% after the introduction of practices designed to aid the skidworkers in their choice of individual stem cutting patterns.

The results of the trial indicate that the AVIS system will be a valuable research tool for quantifying value losses during processing and the identification of where and why these losses occur.

INTRODUCTION

The optimal crosscutting algorithm has been described by research workers in various countries (Pnevmaticos and Mann, 1972). Several authors (Gluck and Koch, 1973; Geerts, 1979) have indicated magnitudes of value loss similar to the case study discussed below. In this paper an effort is made to identify the value loss on the skidsite (landing) where tree length material is converted into log assortments on the basis of human decisions.

Skidworkers have a difficult task to complete. They have to work in a confined area shared with large mobile machines and, given a set of log-making instructions which are ambiguous and/or imprecise, are expected to do rapid assessment of each stem, recognise the various log qualities, and optimise the stem's value.

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The skidworkers' crosscutting decisions will seldom be optimal and will be more difficult with an increasing number of log types. Their choice is very important as they allocate the raw product to the various timber industries, fixing the potential added value.

To implement the optimal crosscutting algorithm there is a need to assess the actual value loss at the skidsite. A computer system has been developed at the Forest Research Institute based on a dynamic programming optimisation formula allowing for data entry of tree parameters and matching skid solution. This system is called AVIS: Assessment of Value by Individual Stems.

DATA COLLECTION METHOD FOR AVIS

The data collection system for program AVIS is based on a tree cruise method similar to that used in the MARVL inventory system (Deadman and Goulding, 1979), but differs in that measurement occurs at harvesting rather than preceding logging planning.

Each stem is cruised after it is felled but before extraction. As with MARVL the stem is assessed regardless of log dimensions and only on quality features — *i.e.*, out-of-roundness, sweep, branch size, surface defects, and nodal swelling.

Assessment of the stem on the ground means that changes in stem quality can be detected accurately along the whole length of the stem. Felled trees seldom lie in contact with the ground along their whole length but rather are suspended above ground by other trees, ground irregularities, branches, and undergrowth. Thus, for much of their length stem quality can be assessed having viewed all sides. The position of changes in stem quality can be measured to the nearest 10 cm.

Rather than using a general volume or taper equation for the calculation of individual volumes, sectional measurements are also made on each stem allowing a more accurate measurement of individual stem volume. Over-bark diameters are measured at the butt and successive fixed intervals along the stem. These intervals are either two, three, or four metres depending on stem length and variation in taper.

AVIS uses a general underbark equation (Gordon, 1983) to estimate underbark diameters for the measured overbark diameters.

The data on stem quality and taper plus the additional details (a unique tree and piece number, the stump height and any butt damage caused by felling, tree d.b.h.o.b., and tree height) of each measured stem are recorded on one field form.

Trees, on falling, usually break into several pieces of which one or more may be of a merchantable size. AVIS enables these pieces to be grouped to calculate the optimal cutting pattern of each piece and maximum value of each tree.

The second portion of the AVIS program is the input of what was cut out of each stem by the skidworkers. This is recorded on a second field form. This is a sequential record, from the large end of each piece, the log type and length, including waste, of each log produced.

Using these data, AVIS calculates the volume and value of logs resulting from the cutting pattern used by the skidworkers, regardless of the qualities of the stem detected during the initial cruise. It also flags those logs cut outside of specification. It then provides a summary of the value of each piece as derived, first, by its optimising procedure and, secondly, by the actual crosscutting and the difference between these two solutions. Summaries are also provided by tree and by groups of trees per run.

A Test Run of AVIS

A tractor logging crew in Kinleith Forest who had a reputation for sustained high levels of productivity was selected for the test field study. They used a Caterpillar D7 pulling a logging arch and a Ruston-Bucyrus 30 boom loader. The stand being harvested was radiata pine "old crop". Results of a stand assessment are given in Table 1.

TABLE 1: STAND ASSESSMENT

Planted/age	1935 (stocking unknown)/48
Treatment	Various portions thinned 1964-71
Mean tree d.b.h.o.b.	53.9 cm
p.m.h.	46.0 m
Live basal area	66.4 m^2/ha
Live stocking	271 stems/ha

As the area harvested was to be relogged by a smaller machine once the tractor crew had finished, they took only the butt stems (the length of stem from the butt up to the first break) and the larger merchantable pieces resulting from felling breakage.

Over the three-month period of this study, the logging crew cut four different log types. These were C and I peeler logs, export logs, sawlogs, and pulplogs. The diameter and length specifications for these log qualities are given in Table 2.

TABLE 2: LOG DIMENSION SPECIFICATIONS AND VALUES

Log Type	*Minimum Length (m)*	*Maximum Length (m)*	*Minimum s.e.l. (cm)*	*Maximum s.e.d. (cm)*	*Value ($/m³ u.b.)*
Peeler	7.89	7.91	35	76	50
Export	12.05	12.15	15	90	25
Sawlog	5.00	13.70	25	76	8
Pulpwood:					
1	4.00	6.00	25	50	4
2	6.00	13.70	15	50	4
3	4.00	5.50	40	120	4
4	4.00	6.00	25	120	4
5	6.00	13.70	15	120	4

There was a decrease in the strictness of the specifications relating to knot size, sweep, out-of-roundness, and stem defects from peelers, through to pulpwood.

The log values for this study were arbitrarily set to create a value differential amongst all of the log types but still reflect potential log values. The high value of peelers relative to other log values meant that the identification of the peeler quality portions of the stem was critical to maximising the stem value in log form. An important feature of this study was therefore a measurement of the ability of the skidworkers to find all of the potential high value logs in each stem with a particular set of characteristics.

The instructions on the priority of log types to be produced followed the relative value of the different log types. Thus high priority was given to recovering all of the potential peelers from the residual stem, then export logs, sawlogs, and pulplogs were to be cut in decreasing order of priority.

There were no restrictions upon the maximum or minimum quantities of any of the log types to be produced throughout the study period.

Two separate samples to assess the skidworkers' ability to maximise value were completed. In each of the samples over 250 cruised stems were processed by the skidworkers.

The first sample acted as the control. No attempt was made to influence the skidworkers' log-making procedure. This gave an indication of the value loss that might be expected to occur under normal logging conditions where a crew with minimal training and supervision is given a set of cutting instructions and a priority with which to cut different log types and left to complete the job.

Measurement for the second sample began two weeks after completion of the first. During this time practices were introduced to improve the skidworkers' log-making to maximise the value obtained from each stem.

Three key features were recognised as important in improving skidsite log-making. They were:

(1) Increasing the skidworkers' awareness of options available to them when choosing the log types of each stem and the effects of their choices of total stem value.
(2) Allowing them time, free of pressure from machinery, to make their decisions.
(3) Giving them suitable measuring equipment to aid them in making their decisions.

Increasing skidworker awareness of log values and options was achieved by a field demonstration and continual discussion and querying of the skidworkers' decisions made during the second sample measurement. Where a better stem cutting pattern was seen by the study team than the one chosen by the skidworkers, particularly if potential peeler and export logs had been lost, the choice of the alternative cutting pattern was discussed with the skidworkers. In the latter stages of the second sample, there were very few instances where the study team were able to query the skidworkers' log choices.

There was therefore some increase in the skidworkers' conversion standards during the second sample as well as between the two samples.

During the control sample measurement the extraction phase had priority over all other work phases — *i.e.*, an aim of maximum volume production. The skidworkers were expected to keep out of the way of the tractor and to complete their log-making activities before the tractor returned with each new haul. Instructing the tractor operator not to come on the skidsite with a new load of stems until the skidworkers had finished processing the earlier load allowed the skidworkers time to make unhurried decisions on log types. The amount of delay this policy caused was recorded. The tractor was infrequently delayed. However, the additional aim of this policy was to transfer some of the importance of the harvesting operation from the extraction to the processing work centre.

Peeler and export log types have specified measurable parameters for out-of-roundness, small and large end diameters, and knot sizes. The skidworkers were initially ill-equipped to measure these accurately so had to estimate and tended to be conservative in their decisions. They did have a tool to measure small end diameters for peelers but this was imprecise and unifunctional, not being able to assist in the measurement of export log s.e.d., out-of-roundness, and knot size measurements.

A set of calipers, graduated in 1 cm increments, were made available to the skidworkers. These were more versatile than tools which they had and could be used to check all of the above parameters.

The basic measure and mark procedure used by the skidworkers was the same for both the first and second samples. Two skidworkers would do all of the measure and mark activities for each haul. The skidworkers used a spring-loaded tape to measure the peeler and export log lengths. The tape was marked at the peeler and export length to facilitate easy reading. Each worker carried a spray can with which to mark where crosscutting should occur and to label the logs with their quality. The skidworkers started at the butt ends of the logs in the haul and moving across the stems would normally measure and work out all of the export and peeler logs in two to four of the stems in the haul. They would then return to the butt ends and measure the remaining logs. Only peeler logs and export were labelled. This was to distinguish them from the sawlog and pulplogs for the loader operator so he would place them in the correct stockpiles for subsequent transfer to trucks. The loader operator made the final decision as to what was sawlog or pulpwood quality, often as he loaded the trucks.

RESULTS OF THE TRIAL

1. *Value Losses from Crosscutting Practice*

As the observed logging crew did not extract all of the merchantable pieces from the stand but rather concentrated on the butt stems, only losses involved in processing the butt stems by the skidworkers are included in this analysis. The height of the first break after felling is most commonly at around two-thirds of the total height of the tree; therefore, the butt stem contains a substantial proporion of both the volume and the value of the tree.

The results from AVIS showed that, under normal (control) skid practice with log values as described above, 26% of potential stem value was being lost from sub-optimal log-making by the skidworkers (Table 3). Much of this loss was from the downgrading of peeler material to export logs. In the optimal cutting strategy, 37% of the volume was in peeler material while the skidworkers produced only 25% in peelers (Table 4). In addition, the average log volume of the export, saw, and pulplogs cut by the skidworkers was higher than in the optimal solutions, indicating a general degrade down through the log grades.

The average value loss during the second (improved practice) sample was 11%, a significant reduction from the control. Downgrading of peeler material was not as great a problem, with the skidworkers producing 43% of their volume in peelers compared with the optimal solution having 38% in peeler material. Upgrading was therefore a source of value loss.

TABLE 3: BUTT STEM VALUE AND VALUE LOST DURING PROCESSING

	1st Sample	*2nd Sample*
Total value if value optimising cutting strategy used ($)	20657	26411
Total value achieved by the skidworkers ($)	15297	23531
Number of stems measured	262	296
Average optimal value per stem ($)	78.8	89.2
Average achieved value per stem ($)	58.4	79.5
Average loss per stem ($)	20.4	9.7
Value lost by sub-optimal processing (%)	26	11

TABLE 4: NUMBERS AND VOLUMES OF VARIOUS LOG TYPES PRODUCED IN MEASURED SAMPLES

Log Type	*Optimal Cutting Strategy*				*Skid Cutting Strategy*			
	No. Logs	*Ave. Vol. (m^3)*	*Total Vol. (m^3)*	*Propn of Vol. (%)*	*No. Logs*	*Ave. Vol. (m^3)*	*Total Vol. (m^3)*	*Propn of Vol. (%)*
First Sample								
Peeler	207	1.29	267.5	37	170	1.08	184.1	25
Export	175	1.33	232.5	32	172	1.66	286.2	39
Sawlog	172	0.75	129.5	18	128	1.02	130.6	18
Pulpwood	186	0.40	73.9	10	229	0.51	116.7	16
Waste	167	0.16	26.6	4	153	0.08	12.4	2
Total	907		730.0	100	852		730.0	100
Second Sample								
Peeler	288	1.30	375.2	38	334	1.28	426.1	43
Export	193	1.41	271.8	28	151	1.16	175.8	18
Sawlog	236	0.87	204.3	21	300	0.91	272.0	28
Pulpwood	180	0.48	86.2	9	191	0.49	94.4	10
Waste	111	0.39	43.4	4	152	0.08	12.6	1
Total	1008		980.9	100	1128		980.9	100

In this analysis all upgraded logs produced by the skidworkers had their value systematically reduced.

The development of skidworkers' awareness of the necessity to identify high value peeler material is apparent when comparing the numbers of peelers they produced to the optimal solution. The within specification peelers recovered in the second sample represent 80% of the potential number available, comparing very favourably with the 48% identified in the control sample.

In both samples the optimal solution given by the program reduces 4% of the total volume to waste. With the goal of maximising stem value the AVIS program will, for example, waste a 2 m length of export quality at the butt if there is sufficient peeler material above this to produce a peeler log. The skidworkers, however, tended to continue a company policy of maximising utilisation, so would be likely to cut a sawlog out of the butt portion of the log in this example. Peeler material would thereby be incorporated in the sawlog and the overall value of the stem reduced.

2. *Log Upgrading*

While downgrading of potential high value logs was the dominant feature of the normal skid practice in this trial, considerable upgrading of logs at the skidsite also ocurred in both samples. Approximately the same proportion of logs were upgraded in each sample, 22% in the control and 24% in the second sample. Upgrading was of three types:

(1) Inclusion of other quality features below specification.
(2) Cutting below allowable s.e.d. limits.
(3) Cutting below length limits.

The proportion of logs upgraded by length increased between the first and second sample from 2 to 5% while the proportion of logs below s.e.d. limits dropped from 10 to 6%. Those with a quality factor upgrade rose from 10 to 13%. Both of the latter changes are most likely the results of the changes made in the skidworkers' procedure between samples.

The reduction in the number of logs below s.e.d. limits would be from the more frequent use of log calipers to check log diameters. The mean s.e.d. (u.b.) of those peeler logs that were cut below the limit (35 cm) rose slightly, from 31.1 cm in the control to 32.7 cm in the second measurement.

Upgrading by the inclusion of below specification quality features was the result of differences in interpretation of log quality specifications between the cruising team in the field and the skidworkers, and also by the missing of downgrading features on the stems by the skidworkers. The proportions of these two sources of differences were not determined. Seventy percent of the logs upgraded by quality in both samples were peeler logs, the majority of upgrading in this class being export quality material.

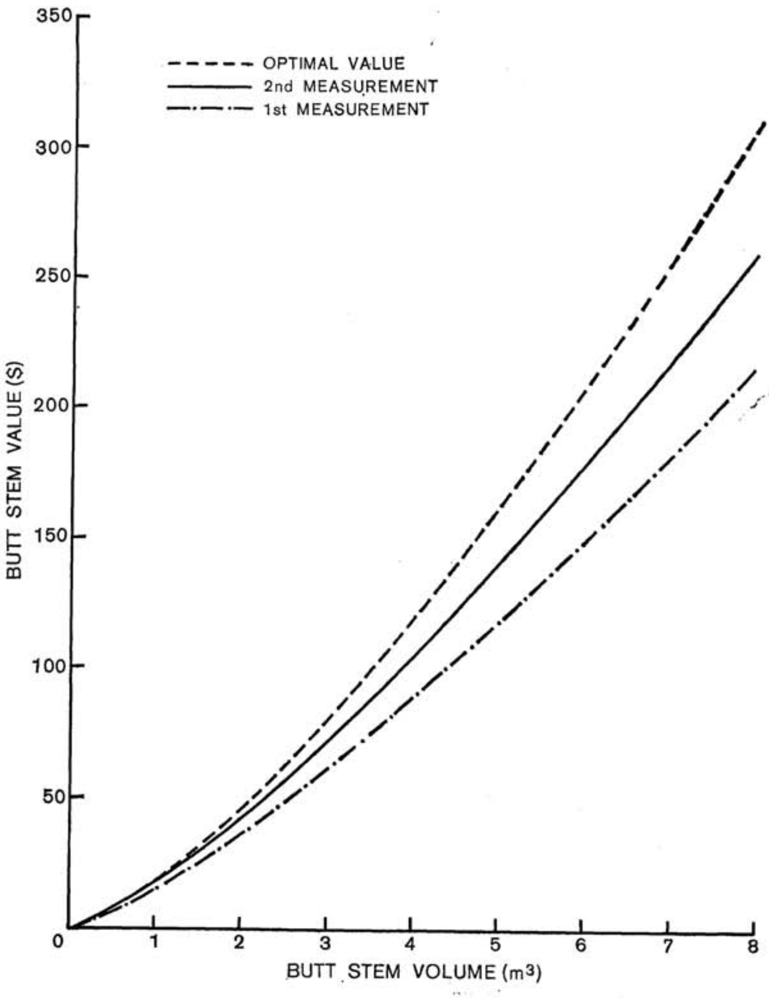

FIG. 1: ***Relationship between butt stem volume and value***

Missing out-of-roundness was responsible for 44% of the upgrading of export quality to peeler quality in the second sample. The use of log calipers by the skidworkers was therefore insufficient to detect the allowable limits of peelers. The amount of out-of-roundness permitted in the specification of peelers was small; therefore, detection of this defect without measurement may be limited to the more obvious occurrences, without regular measurement.

3. *Effect of Tree Size on Value Recovery*

Volume has a marked effect upon value (Fig. 1). The relationship appears to be non-linear. As the butt stem size enlarges, so does the opportunity to cut the larger dimensioned higher value products.

The figure also demonstrates that, as stem volume increases, so does the potential for value loss.

Appropriate non-linear regression models were fitted to relate value to volume. The relation $Y = aX^b$ was used where Y equalled value and X stem volume.

No significant difference (0.05 level) was found between the data for the relationships of value versus volume for the optimal cutting solutions in both samples. These were therefore combined to produce one function. The functions produced for the value from the skid cutting strategy and volume for both the first and second samples were significantly different (0.01 level) from each other and from the optimal value function. The coefficients for the three relationships are given in Table 5.

TABLE 5: COEFFICIENTS FOR RELATIONSHIPS BETWEEN STEM VALUE AND STEM VOLUME

Function $Y = aX^b$	*Coeff. a*	*Coeff. b*
Optimal Solution	18.33	1.36
Skidworkers' solution: second sample	17.48	1.30
Skidworkers' solution: first sample	15.19	1.28

The use of stem diameter (d.b.h.o.b.) did not produce as consistent results as stem volumes because of the influence of breakage. Some large trees in the trial measurement broke during felling at low heights. Their butt stem volume was therefore low relative to their d.b.h., reducing the potential value able to be produced from these stems.

DISCUSSION

In the future more stands being harvested will contain pruned trees. The full realisation of this pruning investment will depend upon the ability of skidworkers to identify correctly the various log qualities and to manufacture logs of the desired dimensions.

This study indicates that under current practice considerable value is being lost by using sub-optimal cutting patterns. With a modest amount of input from management this loss may be reduced. Much more emphasis needs to be placed upon this area of harvesting practice to achieve satisfactory conversion into the desired log grades.

Despite the sub-optimal log conversion shown, the skidsite remains the logical place to make the first log conversion decisions as, in most instances, some processing must be undertaken to meet trucking length requirements. With the provision of clear, precise, log-quality specifications, adequate tools to make dimension measurements, a training programme to develop the skidworkers' ability to choose the correct cutting strategy, and good supervision and quality control, the skidworkers may be able to maintain 90-95% value maximisation. Centralised processing, with a likely requirement for some pre-processing at the landing to meet trucking requirements, may not be able to consistently exceed this, although dimension specification would be more precisely met.

Although not attempted in this study, a financial incentive to produce the higher valued products, combined with the above measures, could be an effective way to increase value maximisation.

AVIS has shown itself to be a valuable research tool for measuring value losses during processing. This full-scale test of the program, as well as providing useful information, indicated specific areas where AVIS could be altered to expand its capacity and also ease the interpretation of its output.

Now that a suitable tool has been developed, additional work must be carried out to produce suitable cutting policies for skidworkers where the stands have been pruned and where a greater variety of log types must be identified.

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